

Estimated Pore Water Concentrations from Bank Soil Samples – KMEP Linnton Terminal

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The purpose of this technical memorandum (TM) is to assess if hydrocarbon-impacted soil in bank soils at the Kinder Morgan Linnton Terminal (the Site) in Portland, Oregon can act as a source of contamination to the Willamette River via a groundwater pathway. The Site is on the west bank of the Willamette River between approximate river miles (RM) 4.1 and 4.3 within the Portland Harbor. Figure 1 shows the site location. This TM presents the approach and results of the partitioning analysis used to estimate dissolved-phase hydrocarbon concentrations in pore water resulting from hydrocarbon-impacted soil along the bank of the Site.

Several bank soil investigations have been performed at the Site. These investigations have included assessment and characterization of erodible soils (CH2M HILL, 2010) and characterization of surface and subsurface bank soils. The erodible soils assessment was completed in November 2010 (CH2MHILL, 2010). The first phase of the bank soil characterization was completed in November 2010 (CH2M HILL, 2011) and a second bank soil investigation was completed in October 2011 (CH2M HILL, 2012). These investigations concluded that bank soil at the Site is not erodible and therefore, the soil is unlikely to be a source of contamination to the Willamette River via the erosion pathway.

This TM presents an assessment of the bank soils to groundwater migration pathway. The potential for this pathway to impact the Willamette River was assessed using a partitioning analysis to estimate dissolved-phase hydrocarbon concentrations in pore water that would result from hydrocarbon-impacted bank soil. The approach uses 3-phase and 4-phase partitioning analyses to estimate pore water concentrations based on measured total petroleum hydrocarbon (TPH) and hydrocarbon compound concentrations in bank soil samples collected at the Site. The 3-phase analysis estimates hydrocarbon concentrations in pore water, pore air, and soil solids (sorbed onto soil organic carbon). The 4-phase analysis includes the residual NAPL phase that is present when sufficient petroleum remains after partitioning into pore water, pore air, and onto soil particles. At sufficiently low TPH concentrations, residual NAPL is not present and the 4-phase analysis reduces to the 3-phase analysis.

The 3- and 4-phase calculations were performed in accord with the equations and assumptions given in Appendix B of the DEQ's *Risk-Based Decision Making for the Remediation of Petroleum Contaminated Sites* (RBDM guidance; DEQ, 2003) and implemented in a manner consistent with the DEQ's Microsoft Excel spreadsheet used to calculate site-specific risk-based concentrations. The methods are consistent with EPA recommended approaches for modeling soil to groundwater (EPA, 1996) and sediment to pore water (EPA, 2003) interactions. For the proposed analysis, the list of compounds was expanded to allow for the explicit inclusion of individual PAHs, VOC hydrocarbons, and aromatic and aliphatic equivalent-carbon group fractions in the calculations.

The calculations conservatively assumed that partitioning occurs under saturated conditions (i.e., air-filled porosity is zero) such that the solver calculates the water-filled porosity and NAPL-filled porosity. This is a conservative assumption in that it keeps that portion of petroleum compounds that may partition into the air phase in the water and NAPL phases.

Site-specific data required by the partitioning calculations include the laboratory analytical data for soil samples, chemical properties for the petroleum compounds, and properties of the soil matrix.

Soil Analytical Data

The analytical data used is based on soil sample results for total petroleum hydrocarbons, PAH results (by method SW8270C), and benzene, ethylbenzene, toluene, xylenes, and naphthalene (by method SW8260B). Analytical data for bank soils samples is summarized in Tables 1 and 2. Table 3 lists compounds that are included in the partitioning analysis, along with the equivalent carbon ranges used to determine carbon ranges for TPH. The detection limit was assumed for analytes that were non-detect in the samples. Following the approach recommended in the DEQ RBDM guidance (DEQ 2003), the equivalent-carbon concentrations were calculated from TPH analytical data for partitioning calculations as follows:

- Total TPH was calculated by summarizing the TPH fractions for gasoline, diesel, and oil range hydrocarbons.
- TPH concentrations for aromatic and aliphatic equivalent-carbon groups were determined by multiplying the total TPH concentration by the equivalent-carbon fractions for diesel from Table 3.2 of the DEQ's RBDM guidance (DEQ, 2003). The assumed equivalent-carbon fractions from the RBDM guidance (DEQ, 2003) are shown on Table 3. NAPL samples collected at the Site, as well as analysis of bank soil samples, indicate that samples impacted by petrogenic hydrocarbons are from a mid-distillate product such as diesel.
- A reduced TPH carbon range concentration was then determined by subtracting the mass of individual petroleum compounds (BTEX, naphthalene, and PAHs) that are explicitly represented in the calculations from the equivalent-carbon group fraction of TPH. Table 3 summarizes the TPH equivalent-carbon range associated with each petroleum compound.

Chemical Properties

Required chemical properties include average molecular weight, single component solubility, Henry's constant, organic carbon partitioning coefficient, and pure phase density. Table 3 summarizes the chemical properties used for the evaluation. Most property values were referenced from Appendix D of DEQ's RBDM Guidance (DEQ, 2003). For larger PAH compounds that are solids at ambient temperatures, the calculated "subcooled liquid solubility" was used rather than the single component solubility. This approach is recommended in guidance developed by the American Petroleum Institute for conducting phase-partitioning calculations (API, 2001) and is utilized in the *Alaska Hydrocarbon Risk Calculator* (ADEC, 2011). For PAHs with melting points above 25 degrees Celsius, the subcooled liquid solubility values were referenced from the *Alaska Hydrocarbon Risk Calculator* (ADEC, 2011).

Soil Properties

Required soil properties include soil bulk density, fraction of organic carbon in soil (f_{oc}), and total soil porosity. The default parameters values identified in the DEQ RBDM guidance (DEQ, 2003) were used for soil bulk density (1.7 g/cm^3) and total porosity (0.38). The average f_{oc} value of 0.013 measured for bank soils samples from the Site (see Table 4), was used for the calculations.

Results and Screening

The partitioning analysis was conducted for samples collected during the 1st phase of the bank soils investigations and for samples collected during the 2nd phase investigation that had a petrogenic signature (borings BA-8 and BA-14). The locations of the bank soils samples are shown on Figure 2. For each boring location, the analysis was conducted for the sample from the most-impacted depth interval. Table 5 summarizes the pore water concentrations estimated by the partitioning analysis.

Samples from the second phase investigation that had a PAH signature indicative of impacts from urban background (PAHs that are pyrogenic in origin) were not included in this evaluation. During the second phase investigation, split samples were collected and evaluated to assess whether the PAH distribution was indicative

of petroleum impacts (i.e., petrogenic in origin) or indicative of pyrogenic PAHs related to urban background. The evaluation concluded that PAHs in the samples from BA-8 and BA-14 are associated with petrogenic sources, the petrogenic source is associated with a mid-distillate product such as diesel, and PAH impacts to samples from other locations are associated with pyrogenic sources. Details on the evaluation will be presented in a forthcoming memorandum.

The estimated pore water concentrations for each compound were screened against the Screening Level Values (SLVs) developed for Joint Source Control (DEQ and EPA, 2007). Because SLVs do not exist for equivalent-carbon group fractions, their pore water concentrations were screened against DEQ's residential and occupational risk-based concentrations (RBCs) for protection of groundwater as drinking water (DEQ, June 2012). Including a residential exposure scenarios is very conservative as no residences are located downgradient of the facility, and shallow groundwater beneath the Site is not used, and cannot be reasonably be anticipated to be used, as a source of drinking water.

Estimated pore water concentrations are below SLVs for all samples. Estimated concentrations for carbon-group fractions are below all occupational drinking water RBCs and below residential drinking water RBCs except for aromatic carbon fraction ranges >C10-C12 and >C12-C16. Here, estimated concentrations exceed the residential RBC by less than a factor of 1.6 for the aromatic >C10-C-12 range, and by less than a factor of 3.5 for the aromatic >C12-C16. These estimated concentrations are for pore water directly in contact with the most impacted samples. Because of dilution associated with groundwater transport and groundwater-surface water interaction, it is expected that concentrations in shallow pore water directly adjacent to surface water would be at lower concentrations. In addition, the model also conservatively assumes equilibrium conditions are present between the soil and groundwater and does not account for other constituents present in groundwater.

The results from this evaluation demonstrate that petroleum impacts in bank soils are unlikely to result in unacceptable concentrations of hydrocarbons in pore water adjacent to the Site. This conclusion is based on a conservative analysis using the most impacted bank soil samples from upgradient areas that estimates hydrocarbon concentrations to be below SLVs, all occupational RBCs, and the majority of residential RBCs. In addition, dilution due to groundwater transport and surface water interaction would be expected to lower concentrations, and any associated risk, at the point where ecological receptors could be exposed to pore water. The results of this analysis will be included in the joint source control evaluation report for groundwater and bank soils.

References

- CH2M HILL, 2010. *Kinder Morgan Linnton Terminal River Bank Erodability Assessment*.
- CH2M HILL, 2011. *Subsurface Bank Soils Investigation Results*.
- CH2M HILL, 2012. *Phase 2 Bank Soils Investigation Results*.
- DEQ, 2003. *Risk-Based Decision Making for the Remediation of Petroleum Contaminated Sites*.
- DEQ, 2012. *Calculating RBCs for Total Petroleum Hydrocarbons*. Excel spreadsheet downloaded from <http://www.deq.state.or.us/lq/rbdlm.htm> on July 18, 2012.
- EPA, 1995. *Soil Screening Guidance: User's Guide*. EPA/540/R-96/018.
- EPA, 2003. *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures*. EPA/600/R-02/013

Table 1
Analytes Detected in Soil, PAH
Kinder Morgan - Linnton Terminal,
Portland, Oregon

PAH - SW8270C (ug/kg)																				
Sample Name	Sample Date	Sample Depth (feet bgs)	Ground Elevation (feet)	Sample Elevation	2-Methyl-naphthalene	Acenap hthene	Acenapht hylene	Anthracene	Benzo (a) anthracene	Benzo (a) pyrene	Benzo(b&k) fluoranthene, isomeric pair	Benzo (g,h,i) perylene	Chrysene	Dibenz (a,h) anthracene	Fluoranthene	Fluorene	Indeno (1,2,3-cd) pyrene	Naphthalene	Phenant hrene	Pyrene
MacDonald PECs and other SQVs					200	300	200	845	1,050	1,450	13,000	300	1,290	1,300	2,230	536	100	561	1,170	1,520
DEQ 2007 Bioaccumulative Sediment SLVs					--	--	--	--	--	--	--	--	--	--	37,000	--	--	--	--	--
BA-5-4.5	12-Nov-10	4.5	14.0	9.5	177 U	1,960	532 U	857	254	279	229	246	418	177 U	752	2,860	177 U	532 U	7,000	1,330
BA-5C-3.5	12-Nov-10	3.5	18.0	14.5	54,200	8,860	1,930 U	14,400	14,500	15,100	6,990	9,030	21,600	1,930 U	8,070	10,200	3,360	1,930 U	53,100	71,600
BA-7-0	26-Oct-11	0	8.8	8.8	25 U	25 U	25 U	25 U	25 U	25 U	50 U	34	27	25 U	35	25 U	29	25 U	25 U	36
BA-7-4	26-Oct-11	4	8.8	4.8	25	140	25 U	37	270	370	460	390	420	58	1,200	57	300	60	470	1,500
BA-8-0	26-Oct-11	0	8.9	8.9	25 U	25 U	25 U	25 U	25 U	25 U	57	25 U	36	25 U	47	25 U	25 U	25 U	25 U	53
BA-8-3.5	26-Oct-11	3.5	8.9	5.4	170	1,500	250	230	230	300	390	250	430	42	1,600	1,300	220	280	2,100	2,000
BA-9-0	26-Oct-11	0	9.3	9.3	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-9-3	26-Oct-11	3	9.3	6.3	45 U	230	40	94	280	300	420	250	380	56	740	53	240	26	770	980
BA-9-4	26-Oct-11	4	9.3	5.3	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-9-8.5	26-Oct-11	8.5	9.3	0.8	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-1-8	11-Nov-10	8	16.6	8.6	16.8 U	59.6	19.6	34.6	59.8	89.7	190	110	102	23.8	127	30.5	92.7	16.8 U	54.1	125
BA-1-9.5	10-Nov-10	9.5	16.6	7.1	172 U	2,950	172 U	996	2,230	650	1,408	274	1,480	172 U	8,930	2,110	246	172 U	4,510	8,080
BA-1-11.5	11-Nov-10	11.5	16.6	5.1	18.1 U	21.9	18.1 U	18.1 U	18.1 U	18.1 U	18.1 U	18.1 U	18.1 U	18.1 U	45.9	18.1 U	18.1 U	18.1 U	25.3	38.1
BA-10-0	26-Oct-11	0	7.7	7.7	25 U	25 U	25 U	25 U	25 U	39	110	47	95	25 U	170	25 U	46	25 U	84	130
BA-10-1	26-Oct-11	1	7.7	6.7	80	2,500	100	210	1,500	2,100	2,200	2,100	1,800	320	5,500	260	1,500	300	620	7,600
BA-10-4.5	26-Oct-11	4.5	7.7	3.2	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-10-7.5	26-Oct-11	7.5	7.7	0.2	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-11-0	26-Oct-11	0	10.9	10.9	25 U	25 U	25 U	25 U	25 U	25 U	50 U	28	25 U	25 U	25 U	25 U	35	25 U	25 U	25 U
BA-11-2.5	26-Oct-11	2.5	10.9	8.4	25 U	240	25	130	550	1,100	1,700	1,500	1,000	200	1,800	57	1,100	89	460	2,500
BA-11-4.5	26-Oct-11	4.5	10.9	6.4	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-11-8.5	26-Oct-11	8.5	10.9	2.4	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-2-4.5	11-Nov-10	4.5	14.0	9.5	19.5 U	144	29.3 U	81.6	72.6	97.1	130	105	89.8	19.5 U	255	233	65.5	39 U	534	366
BA-2-6.5	11-Nov-10	6.5	14.0	7.5	192 U	11,000	575 U	5,810	3,140	1,060	2,270	273	3,110	192 U	22,600	16,400	264	383 U	60,300	14,900
BA-12-0	25-Oct-11	0	8.2	8.2	25 U	25 U	25 U	25 U	55	90	130	130	140	36	67	25 U	89	25 U	25 U	110
BA-12-2.5	25-Oct-11	2.5	8.2	5.7	65 U	340	50	140	810	620	690	510	1,100	170	1,000	31	470	130	590	1,800
BA-12-7	25-Oct-11	7	8.2	1.2	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	30	25 U	25 U	26
BA-13-0	26-Oct-11	0	8.6	8.6	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-13-3.5	26-Oct-11	3.5	8.6	5.1	2,300	2,000	430	940	1,200	850	2,100	1,300	2,100	330	4,200	1,200	950	4,300	6,100	7,500
BA-13-7.5	26-Oct-11	7.5	8.6	1.1	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-3-4.5	9-Nov-10	4.5	14.0	9.5	20 U	23.6	20 U	24.5	41.8	88.0	110	104	58.8	20 U	78.6	28.6	66.4	20 U	47.5	211
BA-3-8	9-Nov-10	8	14.0	6.0	21.5 U	58.0	21.5 U	32.2 U	21.5 U	21.5 U	21.5 U	21.5 U	43.4	21.5 U	49.5	53.6 U	21.5 U	21.5 U	131	90.7
BA-4-5	12-Nov-10	5	14.6	9.6	3,960 U	16,900	5,930 U	7,400	1,020	953	791 U	791 U	1,820	791 U	3,190	41,700	791 U	5,930 U	61,700	6,590
BA-14-0	25-Oct-11	0	9.3	9.3	100 U	25 U	60 U	420	120	270	300	260	350	47	140	300	200	70	320	580
BA-14-2	25-Oct-11	2	9.3	7.3	25 U	1,500	440	670	140	91	110	63	230	25 U	400	2,600	61	1,100	6,600	580
BA-14-4	25-Oct-11	4	9.3	5.3	25 U	63	25 U	25 U	40	25 U	55	38	80	25 U	150	25 U	33	50	130	280
BA-14-7.5	25-Oct-11	7.5	9.3	1.8	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	32	25 U	38	25 U	25 U	25 U	25 U	93
BA-15-0	25-Oct-11	0	7.1	7.1	25 U	25 U	25 U	25 U	25 U	25 U	50 U	30	36	25 U	150	25 U	25 U	25 U	25 U	110
BA-15-1.5	25-Oct-11	1.5	7.1	5.6	25 U	25 U	25 U	25 U	41	55	91	89	77	25 U	120	25 U	68	25 U	50	160
BA-15-8	27-Oct-11	8	7.1	-1.0	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-16-0.5	25-Oct-11	0.5	7.2	6.7	25 U	30	25 U	25 U	53	83	120	120	110	25 U	82	25 U	87	25 U	27	260
BA-16-4	25-Oct-11	4	7.2	3.2	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-16-7	25-Oct-11	7	7.2	0.2	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-18-0.5	27-Oct-11	0.5	7.2	6.7	25 U	25 U	25 U	25 U	25 U	32	50 J	53	38	25 U	48	25 U	47	25 U	25 U	82
BA-18-2.5	27-Oct-11	2.5	7.2	4.7	25 U	25 U	25 U	25 U	41	100	160	150	94	25 U	57	25 U	120	25 U	28	160
BA-18-4.5	27-Oct-11	4.5	7.2	2.7	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U
BA-18-10	27-Oct-11	10	7.2	-2.8	25 U	25 U	25 U	25 U	25 U	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U	25 U

Notes:
ug/kg = micrograms per kilogram
Screening Level Values (SLVs) taken from Table 3-1 of the Portland Harbor Joint Source Control Strategy (JSCS) guidance document, updated July 16, 2007.
Bold = detected result exceeds screening level.

Table 2
Analytes Detected in Soil, VOC and TPH

Kinder Morgan - Linnton Terminal,
Portland, Oregon

		VOC - SW8260B (ug/kg)															TPH (mg/kg)			
Sample Name	Sample Date	Sample Depth (feet bgs)	Ground Elevation (feet)	Sample Elevation	Benzene	Toluene	Ethylbenzene	Xylenes (Total)	n-Butylbenzene	sec-Butylbenzene	Isopropylbenzene	p-Isopropyltoluene	n-Propylbenzene	1,1,2,2-Tetrachloroethane	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	TPH-E (DRO)	TPH-E (ORO)	TPH-P (GRO)	
MacDonald PECs and other SQVs					57	--												3200	9800	1500
DEQ 2007 Bioaccumulative Sediment SLVs					--	--												--	--	--
BA-5-4.5	12-Nov-10	4.5	14.0	9.5	1,150 U	1,150 U	1,150 U	3,450 U	5,740 U	1,680	2,300 U	2,300 U	1,150 U	3,090	1,150 U	1,150 U	8,540	1,240	1,750	
BA-5C-3.5	12-Nov-10	3.5	18.0	14.5	431 U	431 U	431 U	1,293 U	2,160 U	431 U	862 U	961	431 U	1,180	2,820	543	24,100	22,900	1,030	
BA-7-0	26-Oct-11	0.0	8.8	8.8	6.7 U	6.7 U	6.7 U	6.7 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-7-4	26-Oct-11	4.0	8.8	4.8	6.3	9.3	6 U	6 U	--	--	--	--	--	20 U	--	--	690	810	7.1	
BA-8-0	26-Oct-11	0.0	8.9	8.9	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-8-3.5	26-Oct-11	3.5	8.9	5.4	72	11	9 U	9 U	--	--	--	--	--	20 U	--	--	370	690	10	
BA-9-0	26-Oct-11	0.0	9.3	9.3	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-9-3	26-Oct-11	3.0	9.3	6.3	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	2,000	2,800	5.5	
BA-9-4	26-Oct-11	4.0	9.3	5.3	5.3 U	5.3 U	5.3 U	5.3 U	--	--	--	--	--	20 U	--	--	61	100 U	5 U	
BA-9-8.5	26-Oct-11	8.5	9.3	0.8	5.9 U	5.9 U	5.9 U	5.9 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-1-8	11-Nov-10	8.0	16.6	8.6	270 U	270 U	270 U	810 U	1,350 U	270 U	540 U	540 U	270 U	270 U	270 U	270 U	131	231	11.9 U	
BA-1-9.5	10-Nov-10	9.5	16.6	7.1	297 U	297 U	297 U	891 U	1,480 U	297 U	594 U	594 U	297 U	297 U	297 U	297 U	243	274	13 U	
BA-1-11.5	11-Nov-10	11.5	16.6	5.1	238 U	238 U	238 U	715 U	1,190 U	238 U	477 U	477 U	238 U	238 U	238 U	238 U	17 U	34 U	11 U	
BA-10-0	26-Oct-11	0.0	7.7	7.7	6 U	6 U	6 U	6 U	--	--	--	--	--	20 U	--	--	49	220	5 U	
BA-10-1	26-Oct-11	1.0	7.7	6.7	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	270	400	5 U	
BA-10-4.5	26-Oct-11	4.5	7.7	3.2	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-10-7.5	26-Oct-11	7.5	7.7	0.2	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-11-0	26-Oct-11	0.0	10.9	10.9	5.4 U	5.4 U	5.4 U	5.4 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-11-2.5	26-Oct-11	2.5	10.9	8.4	7.4 U	7.4 U	7.4 U	7.4 U	--	--	--	--	--	20 U	--	--	400	770	5 U	
BA-11-4.5	26-Oct-11	4.5	10.9	6.4	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-11-8.5	26-Oct-11	8.5	10.9	2.4	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-2-4.5	11-Nov-10	4.5	14.0	9.5	321 U	321 U	321 U	963 U	1,610 U	321 U	642 U	642 U	321 U	321 U	321 U	321 U	297	139	45.8	
BA-2-6.5	11-Nov-10	6.5	14.0	7.5	274 U	274 U	274 U	822 U	1,370	1,450	548 U	548 U	274 U	378	274 U	274 U	11,400	1,390	501	
BA-12-0	25-Oct-11	0.0	8.2	8.2	5.3 U	5.3 U	5.3 U	5.3 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-12-2.5	25-Oct-11	2.5	8.2	5.7	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	3,200	5,000	5 U	
BA-12-7	25-Oct-11	7.0	8.2	1.2	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-13-0	26-Oct-11	0.0	8.6	8.6	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-13-3.5	26-Oct-11	3.5	8.6	5.1	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	1,400	1,900	5 U	
BA-13-7.5	26-Oct-11	7.5	8.6	1.1	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-3-4.5	9-Nov-10	4.5	14.0	9.5	263 U	263 U	263 U	789 U	1,310 U	263 U	526 U	526 U	263 U	263 U	263 U	263 U	118	92.1	54.0	
BA-3-8	9-Nov-10	8.0	14.0	6.0	439 U	439 U	439 U	1,317 U	2,200 U	439 U	878 U	878 U	439 U	439 U	439 U	439 U	198	94.9	77.1	
BA-4-5	12-Nov-10	5.0	14.6	9.6	3,290 U	3,290 U	3,290 U	9,880 U	40,400	41,200	38,500	6,590 U	42,100	7,120	3,290 U	3,290 U	96,300	7,560	11,800	
BA-14-0	25-Oct-11	0.0	9.3	9.3	19 U	19 U	19 U	19 U	--	--	--	--	--	38 U	--	--	8,400	2,200	24	
BA-14-2	25-Oct-11	2.0	9.3	7.3	270 U	270 U	270 U	270 U	--	--	--	--	--	550 U	--	--	12,000	1,500	310	
BA-14-4	25-Oct-11	4.0	9.3	5.3	5.1 U	5.1 U	5.1 U	5.1 U	--	--	--	--	--	20 U	--	--	650	280	6.4	
BA-14-7.5	25-Oct-11	7.5	9.3	1.8	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-15-0	25-Oct-11	0.0	7.1	7.1	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	50	150	5 U	
BA-15-1.5	25-Oct-11	1.5	7.1	5.6	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	78	200	5 U	
BA-15-8	27-Oct-11	8.0	7.1	-1.0	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-16-0.5	25-Oct-11	0.5	7.2	6.7	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	88	100 U	5 U	
BA-16-4	25-Oct-11	4.0	7.2	3.2	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-16-7	25-Oct-11	7.0	7.2	0.2	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-18-0.5	27-Oct-11	0.5	7.2	6.7	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	55	150	5 U	
BA-18-2.5	27-Oct-11	2.5	7.2	4.7	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-18-4.5	27-Oct-11	4.5	7.18	2.68	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	
BA-18-10	27-Oct-11	10.0	7.2	-2.8	5 U	5 U	5 U	5 U	--	--	--	--	--	20 U	--	--	25 U	100 U	5 U	

Notes:

mg/kg = milligrams per kilogram

ug/kg = micrograms per kilogram

Screening Level Values (SLVs) taken from Table 3-1 of the Portland Harbor Joint Source Control Strategy (JSCS) guidance document, updated July 16, 2007.

Bold = detected result exceeds screening level.

Table 3
Chemical Data Used for Evaluation

Kinder Morgan - Linnton Terminal,
Portland, Oregon

Fuel Fraction or Compound	Generic Diesel Weight Fraction	MW (g/mol)	Single-Component Solubility (mg/L)	Subcooled Liquid Solubility (mg/L)	Solubility Used in Calcs (mg/L)	Koc (cm ³ /g)	Henry's Constant [-]	Pure Phase Density (g/cm ³)	Associated Equivalent-Carbon Group
Aliphatic C5-C6	0	81	3.6E+01	--	3.6E+01	7.9E+02	33	0.68	
Aliphatic >C6-C8	0	100	5.4E+00	--	5.4E+00	4.0E+03	50	0.73	
Aliphatic >C8-C10	0.02	130	4.3E-01	--	4.3E-01	3.2E+04	80	0.73	
Aliphatic >C10-C12	0.071	160	3.4E-02	--	3.4E-02	2.51E+05	120	0.76	
Aliphatic >C12-C16	0.354	200	7.6E-04	--	7.6E-04	5.01E+06	520	0.77	
Aliphatic >C16-C21	0.343	270	2.5E-06	--	2.5E-06	6.31E+08	4900	0.78	
Aliphatic >C21-C34	0	400	1.5E-11	--	1.5E-11	1.07E+10	100000	0.78	
Aromatic >C8-C10	0.0025	120	6.5E+01	--	6.5E+01	1.58E+03	0.48	0.87	
Aromatic >C10-C12	0.0075	130	2.5E+01	--	2.5E+01	2.51E+03	0.14	0.90	
Aromatic >C12-C16	0.081	150	5.8E+00	--	5.8E+00	5.01E+03	0.053	1.02	
Aromatic >C16-C21	0.121	190	6.5E-01	--	6.5E-01	1.58E+04	0.013	1.23	
Aromatic >C21-C34	0	240	6.6E-03	--	6.6E-03	1.26E+05	0.00067	1.28	
Benzene	--	78	1.75E+03	--	3.60E+01	5.89E+01	0.23	0.88	
Toluene	--	92	5.26E+02	--	3.60E+01	1.82E+02	0.28	0.87	
Ethylbenzene	--	106	1.69E+02	--	3.60E+01	3.63E+02	0.33	0.87	Aromatic >C8-C10
Total Xylenes	--	106	1.75E+02	--	3.60E+01	3.86E+02	0.28	0.88	Aromatic >C8-C10
Naphthalene	--	128	3.10E+01	--	3.60E+01	2.00E+03	0.02	1.15	Aromatic >C10-C12
2-Methyl-naphthalene	--	142	2.46E+01	3.05E+01	3.05E+01	2.98E+03	2.12E-02	1.15	
Acenaphthene	--	154	4.24E+00	1.86E+01	1.86E+01	4.90E+03	6.45E-03	0.77	Aromatic >C12-C16
Acenaphthylene	--	152	1.61E+01	7.51E+01	7.51E+01	6.12E+03	5.11E-03	0.77	Aromatic >C12-C16
Anthracene	--	178	4.34E-02	3.31E+00	3.31E+00	2.95E+04	2.70E-03	0.78	Aromatic >C16-C21
Benzo(a) anthracene	--	228	9.40E-03	1.95E-01	1.95E-01	3.98E+05	1.39E-04	1.28	Aromatic >C21-C34
Benzo(a) pyrene	--	252	1.62E-03	5.19E-02	5.19E-02	1.02E+06	4.70E-05	1.28	Aromatic >C21-C34
Benzo (b) fluoranthene	--	252	1.50E-03	3.91E-02	3.91E-02	1.23E+06	4.62E-03	1.28	Aromatic >C21-C34
Benzo (k) fluoranthene	--	252	8.00E-04	6.38E-02	6.38E-02	1.23E+06	3.45E-05	1.28	Aromatic >C21-C34
Benzo(b&k) fluoranthene	--	252	1.15E-03	5.15E-02	5.15E-02	1.23E+06	2.33E-03	1.28	Aromatic >C21-C34
Benzo(g,h,i) perylene	--	276	2.60E-04	8.34E-02	8.34E-02	2.68E+06	1.35E-05	1.28	Aromatic >C21-C34
Chrysene	--	228	1.60E-03	4.06E-01	4.06E-01	3.98E+05	3.93E-03	1.28	Aromatic >C21-C34
Dibenz (a,h) anthracene	--	278	2.49E-04	2.75E-01	2.75E-01	3.80E+06	6.11E-07	1.28	Aromatic >C21-C34
Fluoranthene	--	202	2.06E-01	1.73E+00	1.73E+00	1.07E+05	6.70E-04	1.28	Aromatic >C21-C34
Fluorene	--	166	1.98E+00	1.47E+01	1.47E+01	1.38E+04	2.64E-03	1.28	Aromatic >C21-C34
Indeno(1,2,3-cd) pyrene	--	276	2.20E-05	4.50E-03	4.50E-03	3.47E+06	6.65E-05	1.28	Aromatic >C21-C34
Phenanthrene	--	178	1.15E+00	6.25E+00	6.25E+00	2.08E+04	4.23E-05	1.28	Aromatic >C21-C34
Pyrene	--	202	1.35E-01	2.39E+00	2.39E+00	1.05E+05	4.58E-04	1.28	Aromatic >C21-C34

NOTES:

Unless noted otherwise, values are from *Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites* (DEQ, 2003).

Highlighted cells - data derived from the Alaska *Hydrocarbon Risk Calculator* (ADEC, 2011).

Assumed density from the appropriate aromatic carbon range.

The pure phase density for naphthalene was used for 2-methyl-naphthalene.

Benzo(b&k) fluoranthene -chemical property values are the average value from Benzo(b) fluoranthene and Benzo(k) fluoranthene.

Table 4**Organic Carbon Data***Kinder Morgan - Linnton Terminal,**Portland, Oregon*

	Units	BA-7-4	BA-8-3.5	BA-9-3	BA-10-1	BA-11-2.5	BA-12-2.5	BA-13-3.5	BA-14-2	BA-15-1.5	BA-16-0.5	BA-18-2.5	Average
Total Organic Carbon	mg/kg	10,500	3,990	20,600	19,100	16,100	13,000	32,300	7,810	9,040	2,430	13,200	13,000
Fraction of Organic Carbon	unitless	0.0105	0.00399	0.0206	0.0191	0.0161	0.013	0.0323	0.00781	0.00904	0.00243	0.0132	0.013

NOTES:

Total organic carbon analyzed by method SM20 5310B modified by Batelle Memorial Institute laboratory.

Table 5
Estimated Pore Water Concentrations

Kinder Morgan - Linnton Terminal,
 Portland, Oregon

Chemical	Estimated Pore Water Concentrations (ug/L)							Portland Harbor SLVs		DEQ RBC Values for Generic Diesel	
	BA-1-9.5	BA-2-6.5	BA-3-8	BA-4-5	BA-5C-3.5	BA-8-3.5	BA-14-2	MacDonald PECs and other SQVs	DEQ 2007 Bioaccumulative Sediment SLVs	Residential Exposure	Occupational Exposure
Aliphatic C5-C6	0	0	0	0	0	0	0	--	--	1,500	6,100
Aliphatic >C6-C8	0	0	0	0	0	0	0	--	--	1,500	6,100
Aliphatic >C8-C10	10	13	13	13	13	12	13	--	--	130	550
Aliphatic >C10-C12	3	3	3	3	3	3	3	--	--	130	550
Aliphatic >C12-C16	0	0	0	0	0	0	0	--	--	370	1,500
Aliphatic >C16-C21	0	0	0	0	0	0	0	--	--	110,000	440,000
Aliphatic >C21-C34	0	0	0	0	0	0	0	--	--	110,000	440,000
Aromatic >C8-C10	6	228	259	259	260	90	235	--	--	2.E+19	9.E+19
Aromatic >C10-C12	86	268	289	289	285	135	269	--	--	180	730
Aromatic >C12-C16	330	611	636	636	630	455	622	--	--	180	730
Aromatic >C16-C21	76	84	84	84	84	82	84	--	--	180	730
Aromatic >C21-C34	0	0	0	0	0	0	0	--	--	1,500	5,800
2-Methyl-naphthalene	4	1	1	1	48	3	0	200	--	--	--
Acenaphthene	36	18	4	4	4	15	2	300	--	--	--
Acenaphthylene	2	3	5	5	3	3	2	200	--	--	--
Anthracene	2	1	0	0	1	0	0	845	--	--	--
Benzene	53	2	3	3	1	6	2	57	--	44	180
Benzo (a) anthracene	0	0	0	0	0	0	0	1,050	--	--	--
Benzo (a) pyrene	0	0	0	0	0	0	0	1,450	--	--	--
Benzo(b&k) fluoranthene	0	0	0	0	0	0	0	13,000	--	--	--
Benzo (g,h,i) perylene	0	0	0	0	0	0	0	300	--	--	--
Chrysene	0	0	0	0	0	0	0	1,290	--	--	--
Dibenz (a,h) anthracene	0	0	0	0	0	0	0	1,300	--	--	--
Ethylbenzene	26	1	2	2	1	0	1	--	--	1300	5500
Fluoranthene	5	3	0	0	0	1	0	2,230	37,000	--	--
Fluorene	10	18	6	6	4	6	3	536	--	--	--
Indeno (1,2,3-cd) pyrene	0	0	0	0	0	0	0	100	--	--	--
Naphthalene	5	1	3	3	2	7	4	561	--	6.2	26
Phenanthrene	14	28	4	4	8	5	3	1,170	--	--	--
Pyrene	5	2	0	0	3	1	0	1,520	1,900	--	--
Toluene	37	2	2	2	1	1	2	--	--	2300	9200
Total Xylenes	77	4	6	6	2	0	1	--	--	200	850

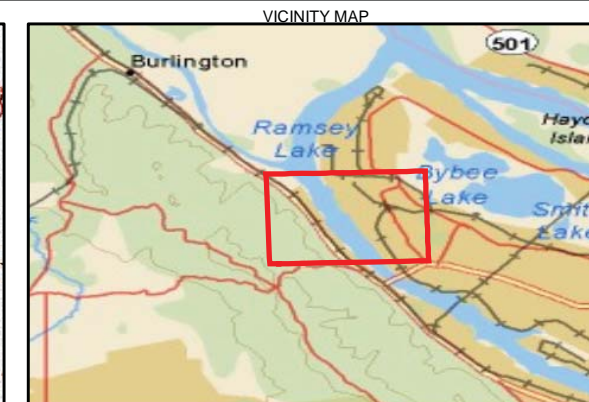
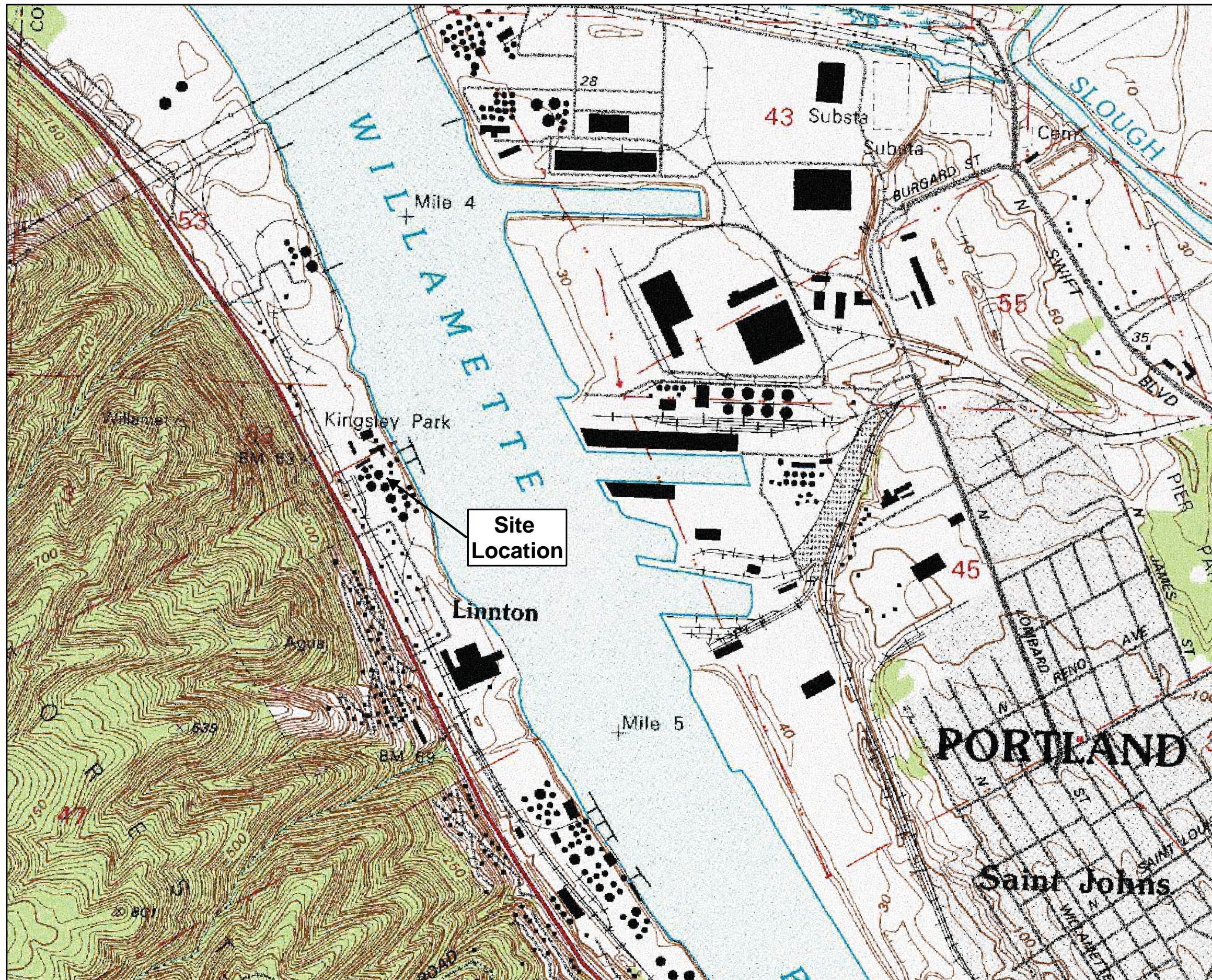
Notes:

ug/L = micrograms per liter

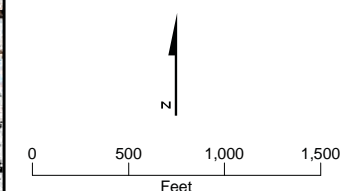
Screening Level Values (SLVs) taken from Table 3-1 of the Portland Harbor Joint Source Control Strategy (JSCS) guidance document, updated July 16, 2007.

Oregon Department of Environmental Quality (DEQ) Risk-Based Concentration (revised June 2012), <http://www.deq.state.or.us/lq/rbdc.htm>

Bold = detected result exceeds DEQ RBC for residential exposure scenario. Value does NOT exceed the RBC for occupational exposure scenario.

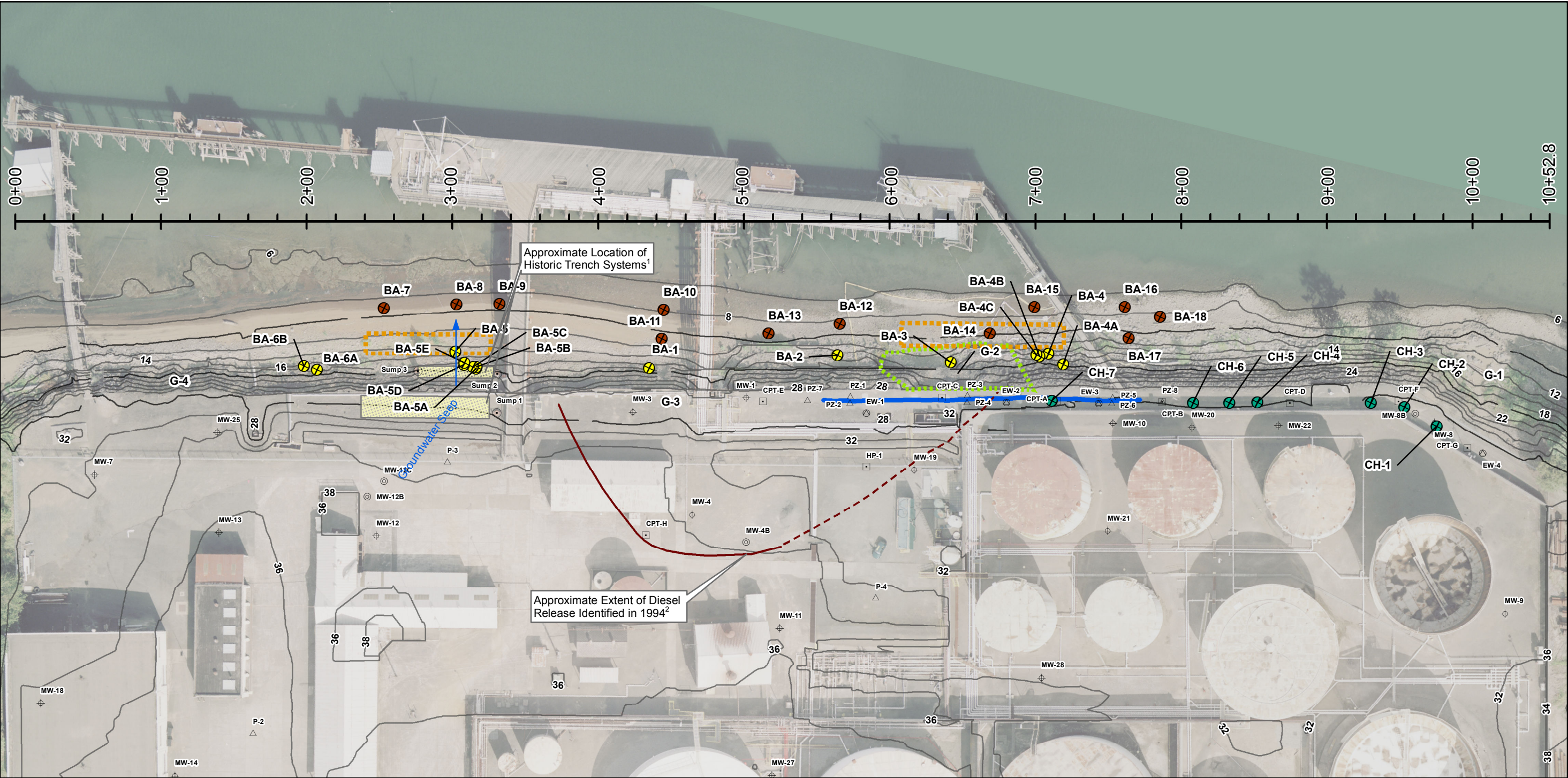


LEGEND



1 inch = 1,000 feet

FIGURE 1
Site Location Map
 Kinder Morgan
 Multnomah County, OR



VICINITY MAP



LEGEND

- Sheet Pile Wall
- Extent of Bank Soil
- Historic Trench System
- Approximate Area Where Sheen was Observed
- Approximate Extent of Diesel Release Identified in 1994
- Extent of Gravel Fill
- Ground Surface Contours**
 - 10-ft Contour
 - 2-ft Contour

Bank Soil Sample Points

- Phase 1 Bank Soil Sample
- Phase 2 Bank Soil Sample
- LNAPL Mobility Study Boring

Linnton Terminal Wells

- Monitoring Well - Deep
- Monitoring Well - Shallow
- Piezometer
- Hydraulic Control Well for Wall
- 3-Foot Diameter Cistern
- Direct Push Boring

References:

- Based on details presented in letter from Harry DeMaray of GATX to DEQ dated August 4, 1992.
- Based on results of direct-push investigation presented in Subsurface Environmental Site Assessment Reoprt (AGRA, 1996)

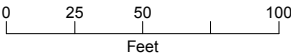


FIGURE 2
Bank Soil Sampling Locations
Kinder Morgan Liquid Terminals LLC
Linnton Terminal
11400 NW St. Helens Road
Portland, Oregon